## Performance Surveillance and Evaluation Systems Using Smart Sensor Structures

How will we monitor nuclear waste storage systems in 2020, 2090, 3090, and beyond? All nuclear electric power and nuclear weapons societies have this leadership responsibility at every level—executive, legislative, judicial, regulatory, scientific, engineering, industrial, and respective citizenry—to develop cooperative understanding, confidence, acceptance, and action as a necessary goal and activity in the safe management of spent fuel (SF) and high-level waste glass (HLWG), showing that the selected monitoring system can always be demonstrably reliable and accurate to initiate corrective action upon detecting incipient degradation of waste forms (WF) and engineered barrier systems (EBS) after emplacement.

The objective of this letter is to identify and discuss a smart sensor structure concept for performance surveillance and evaluation systems (PSES) for interim dry cask storage and the repository waste package (RWP) of SF and HLWG in pre-closure and post-closure modes. The smart sensor structure would provide detection, measurement, evaluation and decision system capability. Some specific essential requirements and capabilities for PSES are listed in the following:

- Maintain a specified accuracy and sensitivity for a specified lifetime performance.
- Maintain the capability to measure, evaluate and record specified degradation (i.e., alteration) rates of storage and repository components based on frequency of measurement—continuous or discrete.
- Maintain the capability to function reliably in the storage and repository environment, i.e., atmospheric, thermal, radiation, chemical, and mechanical.
- Maintain the capability to verify measurements and degradation rates and then trigger setpoint decisions for investigation and decisions for change.
- Maintain the capability of decision-making redundancy.

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- Record, store, and analyze measurement and comparison data, with efficient accessibility to decision-makers over the functional lifetimes of storage and repository facilities.
- Be compatible to periodic calibration checks of total system with associated QA/QC for verification of performance requirements using specially trained scientific and engineering personnel.

The technical goal is to demonstrate the feasibility to implement ongoing operating surveillance and performance evaluation with an appropriate detection and processing system to transmit and interpret the information on the condition of the waste forms and barrier systems. The smart material (SM) could be embedded in barrier materials, or placed on waste forms, or placed in coupons external to the waste form or barrier system.

Characteristics like corrosion depth, nuclide mobilization/migration, stress levels, and moisture need to be monitored with a particular sensitivity. Corrosion potentials, range energy relations, embedded radioactive, and/or light stimulated materials, stress sensors, radiation spectroscopy, luminescence, eddy current testing, and visual profilometry can be considered in the detection, measurement, and evaluation processes.

Finally, in the broadest sense, the motivation for this letter can be summarized with the following objectives:

- Create confidence in stakeholders related to PSES performance.
- Establish "intensive care unit" (ICU) surveillance and response systems for dry cask storage and repository preclosure and post-closure modes. By an "ICU" system we mean a PSES that monitors all the required parameters of the environment, waste form, and the respective engineered barriers of the cask storage system and repository waste package with the necessary accuracy and lifetime reliability and also provide lifetime data processing capability so that appropriate corrective actions can be made upon detection of incipient degradations or failures that could affect licensed operations. By environment, we mean both external and internal of the repository waste package and interim cask storage.

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- Stimulate conceptual feasibility, design, testing, installation, operations, and generation of standards activities for PSES system
- Integrate PSES with interim storage and repository support laboratories.
- Identify and verify performance, calibration, hardening, lifetime and data processing requirements for PSES materials and systems
- Support Licensing of interim and repository storage systems

Additional information on smart sensors can be gathered from the following resources:

E. Kuhn, D. Blauvelt, and G. Smith, "Materials Partial Special Issue: Introduction," *Nucl. Technol.,* **155,** *2,* 119 (2006).

V.K. Wadhawan, *Smart Structures. Blurring the Distinction Between the Living and the Non-Living,* p.195, Oxford University Press (2007).

M.J. Schulz, A. Kelkar, and M.J. Sundaresan, *Nanoengineering of Structural, Functional, and Smart Materials,* CRC, Taylor & Francis (2006)

E. Kuhn, "Workshop on Performance Surveillance and Evaluation Systems"(Session D), Second Seminar on Accelerated Testing of Materials in Spent Nuclear Fuel and High-Level Waste Storage Systems, Sponsored by ASTM Committee C26 on Nuclear Fuel Cycle and Subcommittee C26.13 on Spent Nuclear Fuel and High Level Waste, Jan. 31–Feb. 1, 2008, Tampa, Fla.

*Nuclear Techniques in the Basic Metal Industries,* Proceedings of a Symposium, IAEA, Helsinki, 31 July-4 August, 1972, IAEA, Vienna (1973). STI/PUB 314 (Papers on monitoring, dimensions, composition, welds, moisture, pitting corrosion using Auger electrons, films, etc.)

E. Kuhn, D. Blauvelt, and G. Smith, "Accelerated Testing of Materials Partial Special Issue: Foreword," *Nucl. Technol.,* **176,** *1,* 1 (2011).

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